

DOCUMENT RESUME

ED 272 396

SE 046 892

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TITLE The Effect of the Korean Number System on Young Children's Arithmetic.
PUB DATE [86]
NOTE 18p.; Paper presented at the Annual Meeting of the American Educational Research Association (67th, San Francisco, CA, April 16-20, 1986).
PUB TYPE Reports - Research/Technical (143) -- Speeches/Conference Papers (150)
EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS Arithmetic; *Computation; Elementary Education; *Elementary School Mathematics; Foreign Countries; *Mathematics Achievement; Mathematics Education; *Mathematics Skills; Non Western Civilization; Numbers; *Number Systems
IDENTIFIERS *Korea; Mathematics Education Research

ABSTRACT

Reasons which account for Asians' superiority in mathematics achievement are discussed in this paper. It is suggested that the regularity of the Oriental number system facilitates counting, calculation, and concepts. This paper reviews a study which sought to determine whether and how the structural regularity of a counting system affected the early learning of arithmetic and contributed to the achievement differences between Korean and American children. Results of the investigation, which involved Korean children from ages 3 to 11 years (N=180), supported the proposition that the regularity of the Korean System R (which employs numbers only from one to nine with the rest as compound numbers formed by a regular generative rule) facilitates the acquisition of generative rules of counting. It was shown that Korean children master the generative rules in the R system and use them to attain higher levels of achievement in counting than do American children. Tables are included which specify the basics of the two Korean number systems and outline the tasks and procedures of the experiment. (ML)

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The Effect of the Korean Number System on Young Children's Arithmetic

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School age children in Asian countries such as China, Japan, and Korea display higher levels of mathematics achievement than do children in the U.S. Cross-national research has suggested various factors that might be responsible for the Asians' superior mathematics achievement. Among them are more intensive processes of schooling, a higher level of educational aspiration, and stronger family pressures (Husen, 1967; Stevenson et al., 1985; Stigler et al., 1982). Research suggests that higher intelligence or superior thought processes are not responsible for the difference. For example, our own research (Song & Ginsburg, 1985) has shown that at the preschool level Korean children display a weaker "informal mathematics" than do American children. The former do not begin school with a "head start" in mathematical thinking.

In the present study we propose that another factor contributes to the Asian superiority in mathematics achievement, namely the Oriental number system. Our general hypothesis is that the regularity of this system facilitates counting, calculation, and concepts. Our evidence is derived from a unique natural experiment. In Korea, two number systems are in simultaneous use. One is somewhat irregular, like the American, and the other regular (typical of the Oriental). This situation allows a test of the hypothesis that regularity of the number system facilitates various aspects of mathematical achievement. We begin by

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describing the two systems and then raise some questions concerning their effects.

Korea has a unique dual number system that is different from that of the U.S. as well as those of other Asian countries such as China and Japan. One system, similar to the Chinese and Japanese, is very regular (and hence we call it System R). It employs primitive, arbitrary numbers from 1 to 9 only; the rest are compound numbers formed by a completely regular generative rule. Thus, system R renders the numbers from ten to twenty as "ten-one, ten-two, ten-three...two-ten." Moreover, system R has a more regular "decades" system than does the English: thus "ten, two-ten, three-ten...nine-ten." System R is typically used in reading and writing numerals and is employed almost exclusively in formal school instruction. System R is usually introduced by parents or preschool teachers when the child is around 4 or 5 years of age.

The second Korean number system is more informal and irregular (hence system I). It is generally used in counting objects rather than in written work. System I does not involve the irregularities of counting from "eleven" to "twenty" as the American system does, but does include irregularities in decade number words. System I is usually learned informally during the preschool years. It is not taught in school. Table 1 gives the essentials of both systems.

Insert Table 1 about here

This study investigates the development of the Korean dual number system to determine whether and how the structural regularity of a counting system affects the early learning of arithmetic and contributes to achievement differences between Korean and American children. We examine how Korean children cope with the simultaneous learning of the two counting systems; how the regularity of System R affects the early development of counting; and how the regularity of System R affects the learning of basic arithmetic. Today, we shall discuss the first two of these issues. Wherever possible, we compare our results with comparable data derived from Miller (1985) concerning Chinese children and from Fuson et al (1982) concerning American children.

Method

Subjects

Subjects in this study were 180 Korean children, 10 boys and 10 girls in each of 9 age groups at yearly intervals from 3 to 11 years. The mean ages for each age group were 3.75, 4.69, 5.53, 6.47, 7.50, 8.42, 9.59, 10.53, and 11.55 respectively. Children at the preschool age levels-- 3, 4, and 5 years-- were sampled from a private child care center; children at the school age levels-- from 6 to 11 years old-- were sampled from a public primary school. Both institutions were located in a middle class area in Busan, Korea. Subjects at each age level were randomly sampled from the same classroom, each of which includes approximately 60 students. Subjects who proved to be mentally retarded or unable to follow the instruction were replaced.

Procedures

The tasks used in this study included (1) counting as high as possible in both number systems; (2) comparing numbers in the two systems; (3) writing numbers in the two systems; and (4) adding and subtracting numbers in the two systems. Only task 1 (counting) was administered to the preschool age groups; all the tasks were administered to the primary school age groups. Table 2 describes the tasks.

Insert Table 2 about here

Subjects were tested individually. The interviews with the preschool age groups were conducted by a Korean professor of psychology. Two primary school teachers administered the tests to the school age groups. The teachers were thoroughly trained beforehand to follow the interview procedures. Subjects were given as much time as they wanted to deliberate or formulate the responses. Individual testing took about 20 minutes on the average. (The procedures for administering tasks are described in Table 3). All the interviews were tape-recorded and transcribed by the first author who is a native speaker of Korean.

Insert Table 3 about here

Results

At first, introduction of the dual counting system may result in confusion. The attempt to learn two different number systems in the preschool years might produce a temporary cognitive overload, with the

result that Korean children may at the outset experience difficulty in learning both systems. The data on accuracy of counting are presented in Table 4. At the ages of 3 and 4, Korean children count relatively poorly in both Systems I and R. Their performance is lower than that of Chinese and American children. (See Table 4.) ^{Fig. 1} By age 5, however, Korean children show a level of performance in System R as high as that of Chinese children and higher than that of American children. At that age, Korean children perform significantly better in System R than in System I. In brief, while the initial attempt to learn the two systems may produce confusion, within a few years Korean children learn to count more accurately in System R than in System I, and indeed surpass American children in counting ability.

and Figure 1

 Insert Table 4 about here

Why does System R permit more accurate counting? System I involves irregular decade words, as in English, but System R is completely regular up to 100. Hence, Korean children should find it easier to develop coherent counting rules in System R than in I. Further, Korean children's counting rules in System R should resemble those of Chinese children, who also use a regular system (Miller, 1985). The results show that Korean children using system I exhibit more errors in decade number words than do Korean children using System R. The latter, in turn, strongly resemble Chinese children. This suggests that the regularity of System R facilitates the development of rules for generating decade words.

The distribution of stopping points in counting also supports this proposition. ^(Fig 2) At the ages of 3 and 4, Korean children show no sign of grasping counting structure in either counting system. When children asked to count as high as possible, their last numbers produced-- the stopping points-- fall at random points, mostly between 3 and 18, in both counting systems. The children's learning of number words seems to involve rote memory without a realization of the underlying structure. However, from the age of 5, most of children's stopping points in System R, but less so in System I, involve 9's-- 19, 29, etc. This suggests that children using System R are struggling to master a generative rule for producing the decades. This result is consistent with Siegler's model of counting (Siegler & Richards, 1983; Siegler & Robinson, 1982).

When Korean children are asked to count in one system, they sometimes mix in numbers from the other system. The results show that this mixture does not begin to appear until the age of 5, when children can generally count higher than 19. ^(Table 5) This implies that at first the two systems are learned separately, segregated from one another. Later, after the age of 5, when children are asked to count in System I, their borrowings from System R involve only decade number words. This shows a sensible preference for the regular decades of System R to the irregular ones of System I. On the other hand, when asked to count in System R, children borrow from System I only the primitive numbers between one and nine. This seems to result from overlearning of the counting numbers below ten when children first learn to count in System I.

When asked to compare the relative magnitude of numbers in the two systems, children at the age of 6 show only 28% correct response to the test items, whereas after the age of 7, the level rises up to around 80%. The ability to compare numbers in two different systems develops rapidly between 6 and 7 years of age, but shows little progress with age beyond the age of 7. Even at the end of primary school level, Korean children seem to experience confusion in the use of two systems around 15% of the occasions.

Discussion

The results of this study generally support the proposition that the regularity of the Korean System R (and by implication the regularity of other Asian counting systems) facilitates the acquisition of generative rules of counting. While Korean children initially find it difficult to learn two counting systems at the same time, they soon master the generative rules which are transparent in the regular system and use them to attain higher levels of achievement in counting than do American children. This facility with counting, and with the base ten structure underlying it, provides Korean children with a sound basis for learning early arithmetic in school. The cognitive advantage provided by the regular number system then combines with other factors like intensive teaching and parental pressures to produce school achievement superior to Americans'.

Table 1
Basics of the two Korean number systems

<u>Numbers</u>	<u>System I</u>	<u>System R</u>
1	Hana (One)	Eel (One)
2	Dool (Two)	Ee (Two)
3	Set (Three)	Sahn (Three)
4	Net (Four)	Sah (Four)
5	Dasut (Five)	Dh (Five)
6	Yusut (Six)	Yook (Six)
7	Ilgoop (Seven)	Chil (Seven)
8	Yudulp (Eight)	Pal (Eight)
9	Ahop (Nine)	Goo (Nine)
10	Yul (Ten)	Sip (Ten)
11	Yul-hana (Ten-one)	Sip-eel (Ten-one)
12	Yul-dool (Ten-two)	Sip-ee (Ten-two)
13	Yul-set (Ten-three)	Sip-sahn (Ten-three)
.	.	.
19	Yul-ahop (Ten-nine)	Sip-goo (Ten-nine)
20	Sumool (Twenty)	Ee-sip (Two-ten)
21	Sumul-hana (Twenty-one)	Ee-sip-eel (Two-ten-one)
.	.	.
30	Sulheun (Thirty)	Sam-sip (Three-ten)
40	Maheun (Forty)	Se-sip (Four-ten)
50	Suin (Fifty)	Dh-sip (Five-ten)
60	Yesun (Sixty)	Yook-sip (Six-ten)
70	Eelheun (Seventy)	Chil-sip (Seven-ten)
80	Yudeun (Eighty)	Pal-sip (Eight-ten)
90	Aheun (Ninety)	Goo-sip (Nine-ten)
100	Baek (One-hundred)	Baek (One-hundred)

Table 2
Tasks

I. Counting as high as possible

1. Counting in System I
2. Counting in System R

II. Comparing numbers in the two different systems

1. six (I) and six (R)
2. fifty-one (I) and thirty-four (R)
3. twenty-two (R) and fifteen (I)
4. seventy-three (R) and seventy-three (I)
5. ninety-nine (R) and eighty-nine (R)
6. twenty-nine (I) and twenty-nine (R)
7. eight (I) and six (R)
8. seventy-four (I) and eighty-three (R)
9. forty-one (R) and sixty-six (I)
10. thirty-five (R) and thirty-five (I)

III. Writing numbers

1. five (R)
2. forty-nine (I)
3. sixty-seven (R)
4. ninety-four (I)
5. sixty-two (I)
6. thirteen (R)
7. fifteen (I)
8. eighty-six (R)
9. ninety-nine (R)
10. thirty-eight (I)

IV. Adding numbers

1. fifty-six and thirty-seven (R)
2. twenty-eight and forty-two (R)
3. five and four (R)
4. seventy-five and nineteen (R)
5. three and five (I)
6. sixty-eight and twenty-two (I)
7. forty-seven and fifteen (I)
8. fifty-four and thirty-nine (I)

V. Subtracting numbers

1. three from eight (R)
2. fifteen from twenty-seven (R)
3. forty-four from seventy-nine (R)
4. thirty-seven from sixty-two (R)
5. four from seven (I)
6. thirteen from eighteen (I)
7. thirty-two from seventy-five (I)
8. twenty-seven from sixty-three (I)

Table 3
Procedures

I. The interviewer says, "I'd like you to count out loud for me."

1. "First, count like this with me: One, two, three... (Say in informal way of counting -- System I--)."

2. "Now, let us count this way: One, two, three... (Say in formal way of counting -- System R--)."

-- Subjects are permitted to count as high as they want, even though errors are included in the process.--

II. I'd like you to compare the following two numbers. You can tell me the bigger number. You can also write it down on the answer sheet, if you want."

1. "Which is bigger, six (System I) and six (System R)?"

2. "Which is bigger, fifty-one (System I) and thirty-four (System R)?"

-- Continues the same way till item 10.--

III. "I'm going to tell you some numbers and I'd like you to write them down on the answer sheet."

1. "Five" (System R)

2. "Forty-nine" (System I)

-- Say ten numbers in the two systems -- five in each system -- in random order as described in task.--

IV. "I'm going to tell you some adding problems. You can write down the numbers I tell you on the answer sheet, if you want. You do not have to write them down, if you do not want."

1. "How much is fifty-six and thirty-seven (System R)?"

-- 4 items in system R are presented first, and 4 items in System I later.--

V. "Now, I'm going to tell you some take-away problems. You can write down the numbers I tell you on the answer sheet, if you want. You don't have to."

1. "How much is eight minus three (System R)?"

-- The order of presentation is the same as in task IV.--

Table 4. Percentage of Children Producing Accurate Counting of Various Lengths

Group	Age	N	0-19	20-29	30-72	72-100	101+	Mean
Korean (I)*	3;6-4;5	23	96	4	0	0	0	9
Korean (R)			96	4	0	0	0	9
Chinese	3;7-4;5	16	0	0	94	6	0	41
American	3;6-4;5	33	79	14	6	0	0	16
Korean (I)	4;6-5;5	25	68	16	12	0	4	25
Korean (R)			64	16	12	0	8	28
Chinese	4;9-5;3	16	0	13	75	0	13	55
American	4;6-5;5	33	45	15	28	12	0	35
Korean (I)	5;6-6;5	25	16	28	36	4	16	62
Korean (R)			16	20	20	8	36	93
Chinese**	5;5-6;5	16	0	0	12	75	12	94
American	Kindergarten	33	18	30	26	4	22	~50

* I refers to System I and R to System R.

** Chinese data from Miller, 1985; American data from Fuson et al., 1982.

Table 5. Percentage of Children Showing Mixed Use in Each Number System

Age	N	Number System	Mixed Use in Decades	Mixed Use in Primitives
3	20	System I	.	.
		System R	.	.
4	20	System I	.	.
		System R	.	.
5	20	System I	17	.
		System R	.	26
6	20	System I	45	.
		System R	.	25
7	20	System I	95	.
		System R	.	10
8	20	System I	70	.
		System R	.	5
9	20	System I	100	.
		System R	.	15
10	20	System I	40	.
		System R	.	70
11	20	System I	50	.
		System R	.	65

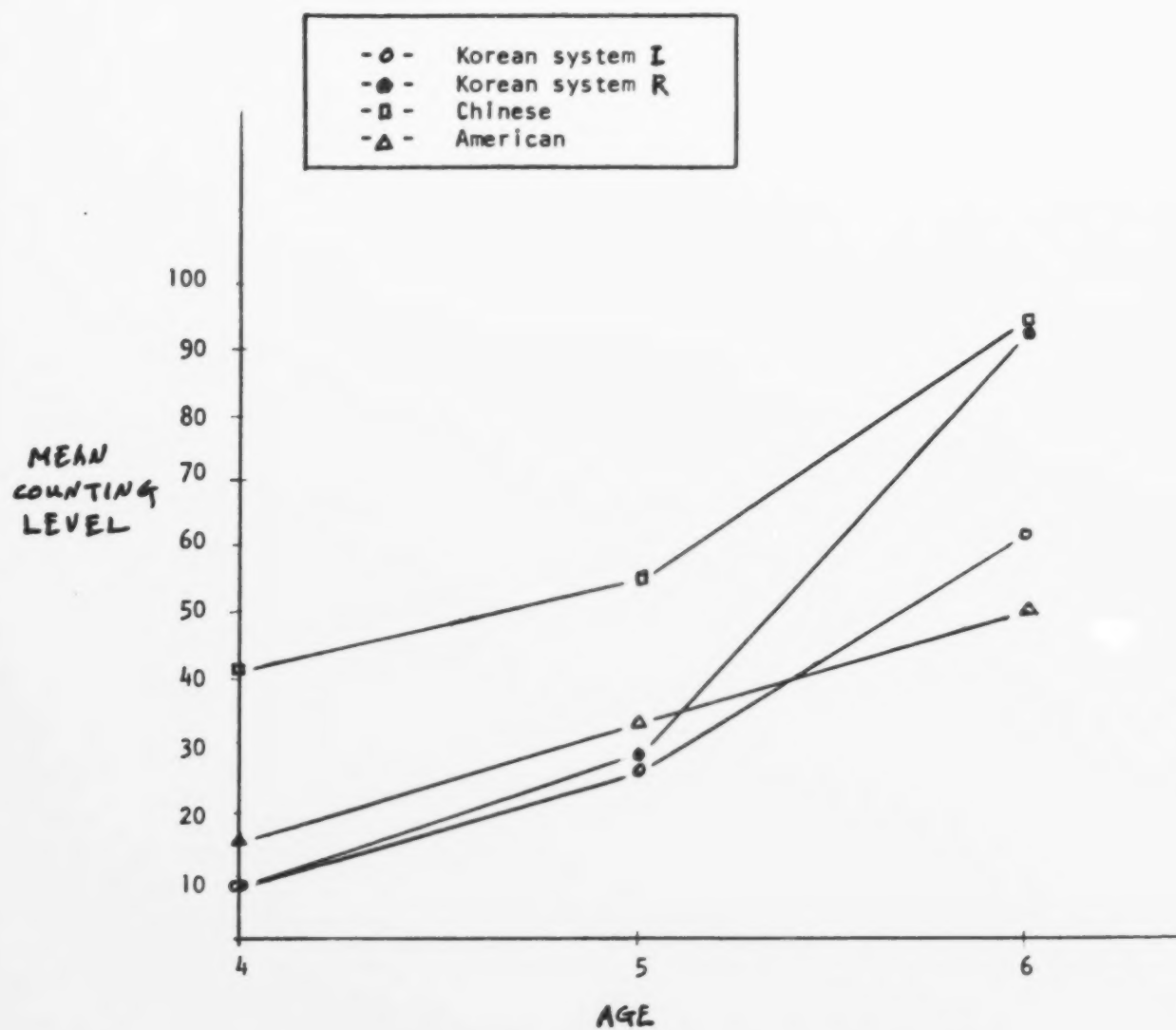
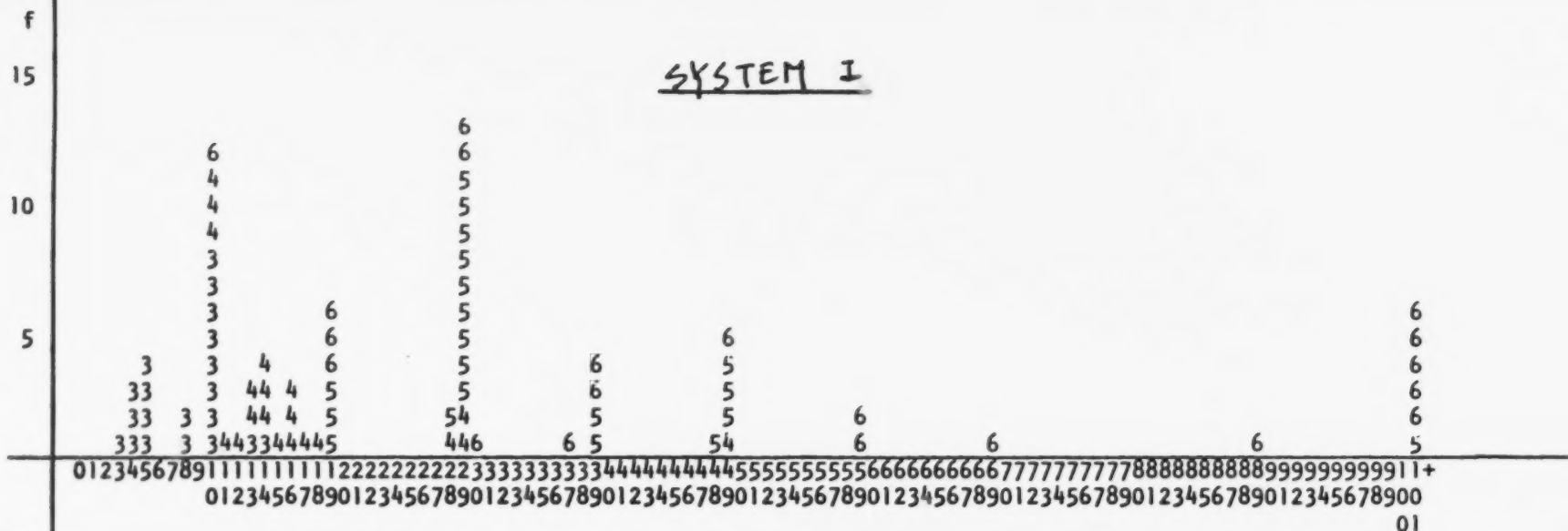


Figure 1. Level of Accurate Counting by Cultural Group



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